

**Implementing Agreement on Technical Cooperation for the
Study of Dynamical Seasonal Prediction of Indian Summer Monsoon Rainfall
between the National Oceanic and Atmospheric Administration of the
Government of the United States of America and the
Ministry of Earth Sciences of the Government of the Republic of India**

Preamble

This text constitutes an Implementing Agreement under Article IV of the Memorandum of Understanding for Technical Cooperation in Earth Observations and Earth Sciences between the National Oceanic and Atmospheric Administration of the United States of America and the Ministry of Earth Sciences of the Republic of India, signed at Washington and New Delhi April 16, 2008 (hereinafter "the MOU").

I. Purpose

This Implementing Agreement provides a framework for collaboration between the Ministry of Earth Sciences (MoES) of India and the National Oceanic and Atmospheric Administration (NOAA), Department of Commerce of the United States of America (hereinafter, "the Parties") concerning the study of Dynamical Seasonal Prediction of Indian Summer Monsoon Rainfall. While intended to serve as a vehicle for continuing collaboration, this Agreement shall be implemented for an initial five-year period within the context of the emerging NOAA-MoES Partnership.

II. Objectives

1. The principal objective of the work embodied within this Implementing Agreement is to develop through dynamical weather prediction models a fuller understanding of the Indian monsoon onset, break and retreat phases and associated precipitation characteristics. This work will contribute to the MoES's "National Monsoon Mission" to provide various Indian economic and agriculture sectors improved weather forecast guidance during the monsoon rainy season. The establishment of a "Monsoon Desk" at NOAA's National Centers for Environmental Prediction (NCEP) will serve as the modality to coordinate numerical model simulations and diagnostics between NCEP, the Indian Institute of Tropical Meteorology (IITM), and the India Meteorological Department (IMD).

2. This Implementing Agreement shall be subject to and governed by the MOU.

III. Areas of Cooperation

1. Dynamical predictions of Indian summer monsoon rainfall are carried out in India through atmospheric General Circulation Models (GCM), which do not include data from the state of the Indian Ocean. Studies show that more than 40 percent of the interannual variations of the Indian summer monsoon rainfall are controlled by oceanic conditions such as sea surface temperature. The actual prediction skills of India's GCMs are degraded as a result of not incorporating ocean data. It is apparent that coupled ocean-atmosphere processes are critical in the monsoon region and need to be incorporated in a GCM to more accurately predict the state of the Indian summer monsoon.

2. Coupled ocean-atmosphere models also require a long development phase to ensure some degree of confidence in the predictions. In order to expedite the implementation of the National Monsoon Mission, the Indian Government, has elected to employ a coupled ocean-atmosphere modeling system that is already developed and tested at NCEP. The NCEP operational Climate Forecast System (CFS) is the model of choice. The NCEP CFS prediction skill for seasonal mean summer rainfall over India is on par with multi-model ensemble forecast systems. NCEP and participating Indian institutes will collaborate to improve the CFS specific to monsoon rainfall predictions for India and more widely for regional Indian Ocean Basin studies.

3. Areas of cooperation under this Implementing Agreement shall include:

- a) Activities that improve the understanding and representation of the climate controls and rainfall for the South Asia region;
- b) Studies that support data collection, data sharing, compilation and processing for societal benefit, including real-time data exchange for operational use;
- c) Studies that support meteorological, hydrological, oceanographic, and climate research including monitoring and understanding of climate forcing and regional scales;
- d) Activities that allow the collaborative and mutual exchange of scientific and technical talent for the enhancement of mutual project activities;
- e) Activities for the conduct of appropriate meetings, workshops and conferences for mutual exchange of scientific and technical knowledge and ideas; and

f) Activities that support one or more international objective as identified in international fora in which NOAA and MoES and cooperating entities participate.

4. Forms of cooperation under the Implementing Agreement shall include:

- a) Access by Indian participating Parties under this Agreement to the National Centers for Environmental Prediction's modeling and data assimilation systems for the purpose of collaborative modeling work to improve such systems for the mutual benefit of India and the United States;
- b) The establishment at the National Centers for Environmental Prediction the modality in the form of a "Monsoon Desk" to facilitate and advance Climate Forecast System modeling work among participating Parties to this Agreement; and
- c) Coordination amongst participating parties of the transition to India NCEP's modeling software and codes, including routine updates, for the Global Forecast System, the Climate Forecast System, the Grid Point Statistical Interpolation Data Assimilation Scheme, and the Global Ocean Data Assimilation System.

5. The Monsoon Desk at NCEP will also serve as a key scientific foci for United States and Indian scientists to advance prediction skills for monsoon variability, improved understanding of Indian Ocean-Atmosphere dynamical interactions and associated impact on weather and climate, and other related and relevant monsoonal studies to advance the state of the monsoon rainfall prediction.

IV. Coordination of Joint Activities

1. Overall coordination of the joint activities shall be the responsibility of the Director of NOAA's National Centers for Environmental Prediction and the Program Office of the Ministry of Earth Sciences.
2. Each Party to this Agreement shall designate a principal contact to serve as the focal point and day-to-day representative for activities carried out under this Agreement. This (these) individual(s) and their full contact information shall be listed in Annex A to this Implementing Agreement, which shall be updated periodically and distributed to both Parties.

3. Each Party to this Agreement shall designate participating principal and collaborating institutional contact information including contact information for principal and collaborating investigators from these institutions. This information shall also be listed in Annex A to this Implementing Agreement, which shall be updated periodically and distributed to both Parties.

V. Responsibilities of the Parties

1. The Parties shall be responsible for coordinating and engaging with other organizational entities in their own countries, as appropriate and necessary, for the completion of the tasks designated pursuant to this Agreement.

2. The Indian Institute of Tropical Meteorology (IITM) will implement the Climate Forecast System (CFS) at the IITM super computer facility in Pune, India and shall make the CFS and products available to the Parties engaged in the monsoon mission. IITM will track CFS changes by Indian and international Partners to this Agreement and integrate them into the CFS system in collaboration with NCEP scientists.

3. The CFS system will also be implemented at the India Meteorological Department (IMD) in New Delhi, India and the system used for making operational weather forecasts. IMD will also participate in verifying the seasonal and extended range forecasts provided by both IITM and NCEP. Active participation of IMD is expected in data assimilation activities and IMD will work towards improvement of forecasts on different time scales.

4. The Parties specifically agree to:

a) National Oceanic and Atmospheric Administration:

- i) Upon receipt of India Government funds, establish a Monsoon Desk at NCEP with facilities necessary to support its operation;
- ii) Facilitate sharing of model codes and assimilation modules related to the Climate Forecast System (CFS V 2.0);
- iii) Support Indian Institute of Tropical Meteorology scientists with CFS software and code upgrades and arrange appropriate training; and
- iv) Collaborate on scientific problems of mutual interest to the Parties that will lead to improved summer monsoon predictions.

b) Ministry of Earth Science

- i) Indian Institute of Tropical Meteorology (hereinafter "IITM"):
 - i. Establish a project focal point at the IITM in Pune;
 - ii. Establish the CFS system on the IITM super computer located in its Pune facility;
 - iii. Share the numerical model tools with participating Partners involved in India's National Monsoon Mission;
 - iv. Organize and integrate the changes made to the modules of the CFS system and exchange them with other Parties to this Agreement; and
 - v. Act as a focal point for all activities related to the National Monsoon Mission as it relates to seasonal and extended prediction periods; and
- ii) India Meteorological Department (hereinafter "IMD"):
 - i. Verify forecasts and participate in data assimilation activities at IMD to improve the skill of forecasts;
 - ii. Establish the GFS system on IMD High Performance Computer and carryout day to day weather forecasts;
 - iii. Participate in assimilation of real-time data into the GFS data assimilation modules;
 - iv. Provide upgrades to the GFS including the data assimilation systems for medium-range weather forecasts;
 - v. Implement the Ensemble Prediction System for medium range weather forecasts;
 - vi. Provide to all Parties under this Agreement verification data for weather and seasonal climate predictions over the Indian sub-continent.

VI. Source of Funding

The Parties have agreed to a recommended budget outlined in Annex B to this Implementing Agreement. Fiscal and Budgetary information involving

transfer and monitoring of funds in support of this Implementing Agreement shall be included in Annex A. In accordance with Article II of the Agreement on Science and Technology Cooperation between the Government of the United States of America and the Government of the Republic of India, done at Washington October 17, 2005 (hereinafter "S&T Agreement"), which is applicable to this Agreement, it is understood that cooperative activities under this Implementing Agreement shall be subject to the availability of appropriated and other funds and personnel.

VII. Intellectual Property Rights

Pursuant to Article VI of the MOU, the protection and distribution of intellectual property created or furnished in the course of cooperative activities under this Implementing Agreement shall be governed by the Article VII and Annex I of the S&T Agreement.

VIII. Entry into Force, Amendment and Termination

1. This Implementing Agreement shall enter into force upon signature and shall remain in force for five years.
2. This Implementing Agreement may be amended or extended at any time by mutual written consent of the Parties. The Parties will review this Implementing Arrangement at least once a year to determine whether it should be amended, renewed, or terminated, and, shall update as required the information provided under Annex A and Annex B.
3. Either Party may terminate this Implementing Agreement at any time by providing sixty (60) days written notice to the other Party. In the event this Implementing Agreement is terminated, each Party shall be solely responsible for the payment of any expenses it has incurred.

Done at Washington / New Delhi in two originals in the English and Hindi languages, both texts being equally authentic.

Done at Washington, November 3, 2010, Washington

Dr. Jane Lubchenco

Administrator

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

DEPARTMENT OF COMMERCE

GOVERNMENT OF THE UNITED STATES OF AMERICA

Shri Nayak 6/11

Dr. Shailesh Nayak

Secretary

MINISTRY OF EARTH SCIENCES

GOVERNMENT OF INDIA

ANNEX A

Contact Information

Investigators and Principal Implementing Institution:

Name of the PIs: Dr. Suryachandra A. Rao (IITM), Dr. Arun Kumar (NCEP), Dr. S.K. Roy Bhowmik (IMD)

Name of Co-PIs: Dr. Atul Kumar Sahai (IITM), Dr. Suranjana Saha (NCEP), Dr. D.R. Pattnaik (IMD)

Collaborating Investigators/Institutions

1.1 IITM PI: Dr. Suryachandra Rao Anguluri (Dynamical Seasonal Prediction)
IITM Co-PI: Dr. Atul Kumar Sahai (Dynamical Extended Range Prediction)

Investigators:

Dr. Hemantkumar Chaudhari
Dr. Subodh Kumar Saha
Dr. Sandeep Pattnaik
Dr. Parthasarathy Mukhopadhyaya

1.2 NCEP PI: Dr. Arun Kumar
NCEP Co-PI: Dr. Suranjana Saha

Investigators:

Dr. Hua-Lu Pan (Climate Forecast System)
Dr. Shrinivas Moorthi (Global Forecast System)
Dr. Dave Behringer (Global Ocean Data Assimilation System)

1.3 IMD PI: Dr. S.K.Roy Bhowmik (Weather Prediction)
IMD Co-PI: Dr. D.R.Pattnaik (Extended Range Prediction)

Investigators:

Dr. Medha Kole, IMD Pune
Dr. O Srijit, IMD Pune
Mr. V.R. Durai, IMD New Delhi

The common points of contacts for this Implementing Agreement are:

Dr. A. Suryachandra Rao
Scientist-E & Program Manager
Program on Seasonal Prediction of Indian Summer Monsoon

Indian Institute of Tropical Meteorology
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Dr. Arun Kumar
Chief, Development Branch, Climate Prediction Center
National Centers of Environmental Prediction (NCEP):
5200 Auth Road, Rm 800, Camp Springs, MD 20746, USA
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Fiscal and Budgetary Communication can be made to

Prof. B.N.Goswami
Director, Indian Institute of Tropical Meteorology
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Dr. Louis W. Uccellini
Director,
National Weather Service, National Centers for Environmental Prediction.
5200 Auth Road, Camp Springs, Maryland 20746, USA

Wire Transfer Information

The Ministry of Earth Sciences (MoES) will transfer funds to the National Oceanic and Atmospheric Administration through:

Federal Reserve Bank of New York
33 Liberty Street,
New York, New York (NY) 10045
Account Name: 13140001 NOAA
Account Number: 021030004 TREAS.NYC
Swift Code: FRNYUS33

The Parties agree that if there is a change regarding the information in this section, the Party making the change shall notify the other Party in writing of such change.

ANNEX B

Implementing Agreement Budget

B.1 Budget Estimates

B.1.1 Budget for research manpower and justification for salaries and wages

Proposed personnel budget to be funded by MoES. MoES will provide funds in U.S. dollars to NOAA (INR 24,000,000 @ US\$=50 INR).

Provide US \$96,000 each year for five (5) years in accordance with the total expected budget costs, which are outlined as follows.

Personnel: The Monsoon Desk will be staffed by one full time person

Annual Budget:

Base Salary:	\$55,000/year
Overhead:	\$33,000/year 60% of base salary (health insurance; social security etc.);
Travel:	\$8,000/year two (2) trips per year from U.S. to India, one each for the NCEP Principal Investigator (PI) and the Monsoon desk personnel;
Sub-total:	\$96,000/year
Five-year budget:	\$480,000 (5 x \$96,000)

B.1.2 Budget for permanent equipment and justification

An appropriate number of workstations will be procured by the IITM to satisfy the needs of the project.

The workstations will facilitate the testing of different and individual modules of the CFS system. Once tested successfully on these workstations, modified modules will be integrated into the CFS system that will ultimately run on the main High Performance Computer system of the IITM/IMD.

B.1.3 NCEP - Monsoon Desk

NCEP will contribute \$100,000/year from its part. This contribution will be for:

- (a) salary and overhead deficit that may not be fully covered by the funding requested as part of the current proposal for the full time person;
- (b) desktop and other hardware for person associated with the Monsoon Desk and for the visitors from IITM and IMD to NCEP; and

(c) procurement of disk space for the storage and transfer of data as part of the collaborative effort.

B.2 Methodology

B.2.1 Task and responsibilities for the Monsoon Desk at NCEP

- (a) coordinate transfer of NCEP modeling software and codes (including routine updates) to IITM and IMD. Model codes include: Global Forecast System (GFS); Climate Forecast System version 2 (CFSv2); Gridpoint Statistical Interpolation (GSI) data assimilation; Global Ocean Data Assimilation System (GODAS);
- (b) assist visitors from IITM and IMD to NCEP in getting familiar with computing infrastructure, model codes, and model simulations;
- (c) facilitate use of Climate Forecast System Reanalysis (CFSR) datasets to IITM for understanding climate variability over the Indian monsoon region;
- (d) facilitate use of Climate Forecast System version 2 (CFSv2) hindcasts, and long simulations to IITM for calibration and evaluation of monsoon predictability and variability;
- (e) provide consultation and support for routine transfer from operational servers of NCEP's operational atmosphere, ocean, and land initial conditions for real-time CFSv2 forecasts at the IITM;
- (f) help coordinate model simulations and diagnostics between IITM and NCEP on key scientific foci of importance for monsoon variability and predictability to improve understanding of ocean processes in the Indian Ocean (e.g., coupled interactions related to the MJO), convective parameterization in the atmospheric models, and, extended-range forecasts of break and active monsoon phases.

B.2.2 Task and responsibilities of the monsoon mission nodal point at the IITM

- (a) setup the CFS system (Version 2.0) including data assimilation modules at IITM;
- (b) share the model system and model outputs with national and international partners involved in the national mission;
- (c) integrate the changes made to the modules by national and international partners in the coupled system and exchange them with NCEP for further fine tuning and implementing the same in the next version of the coupled system;
- (d) organize the collaborative research activities between IITM and NCEP and to work on some scientific problems of mutual interest;

B.2.3 Tasks and responsibilities of the IMD

- (a) setup GFS system on IMD HPC and make operational weather forecasts;
- (b) up-grade the Global Forecast System of IMD for medium range forecasts, data assimilation system (both atmosphere and oceanic component);
- (c) implementation of the Ensemble Prediction Systems for medium range weather forecasts;
- (d) verification of weather and seasonal predictions.

B.3 Work elements and detailed plan of implementation and time schedule

Time Schedule	Activities
0-12 Months	Transfer of CFS 2.0 coupled model and associated data assimilation modules to IITM and setup the model on IITM/IMD HPC
13-24 Months	Carryout free runs, hindcast runs and carefully designed sensitivity experiments to document the strengths and weaknesses of the model over Indian Monsoon region.
25-36 Months	Coordinate the work on improving the model physics/parameterization schemes those needs to be improved.
37-48 months	Integrate the modified schemes in the new version of CFS and test the integrity of the simulations/forecasts
49-60 months	Verify the model forecasts and transfer the new version of the model to IMD for operational purposes.

B.4 Utilization of research results and specific deliverables

The goal of this project is to deliver a useful coupled ocean-atmospheric general circulation model to predict the Indian summer monsoon rainfall. The expected outcome from this effort will enhance the current understanding of the coupled ocean-atmosphere monsoon system over India and will be useful for future studies and further model improvements.